# HR-227 Part I – Nonlinear Pile Behavior in Integral Abutment Bridges


## Abstract

The highway departments of all fifty states were contacted to find the extent of application for integral abutment bridges, to survey the different guidelines used for analysis and design of integral abutment bridges, and to assess the performance of such bridges through the years. The variation in design assumptions and length limitations among the various states in their approach to the use of integral abutments is discussed. The problems associated with lateral displacements at the abutment, and the solutions developed by the different states for most of the ill effects of abutment movements are summarized in the report.

An algorithm based on a state-of-the-art nonlinear finite element procedure was developed and used to study piling stresses and pile-soil interaction in integral abutment bridges. The finite element idealization consists of beam-column elements with geometric and material non-linearities for the pile and lonlinear springs for the soil. An idealized soil model (modified Ramber-Osgood model) was introduced in this investigation to obtain the tangent stiffness of the nonlinear spring elements.

Several numerical examples are presented in order to establish the reliability of the finite element model and the computer software developed. Three problems with analytical solutions were first solved and compared with theoretical solutions. A 40-foot H pile (HP 10 x 42) in six typical Iowa soils was then analyzed by first applying a horizontal displacement $\Delta_H$ (to simulate bridge motion) and no rotation at the top and then applying a vertical load V incrementally until failure occurred. Based on the numerical results, the failure mechanisms were generalized to be of two types: (a) lateral type failure and (b) vertical type failure. It appears that most piles in Iowa soils (sand, soft clay and stiff clay) failed when the applied vertical load reached the ultimate soil frictional resistance (vertical type failure). In very stiff clays, however, the lateral type failure occurs before vertical type failure because the soil is sufficiently stiff to force a plastic hinge to form in the pile as the specified lateral displacement is applied.

Preliminary results from this investigation showed that the vertical load-carrying capacity of H piles is not significantly affected by lateral displacements of 2 inches in soft clay, stiff clay, loose sand, medium sand and dense sand. However, in very stiff clay (average blow count of 50 from standard penetration tests), it was found that the vertical load carrying capacity of the H pile is reduced by about 50 percent for 2 inches of lateral displacement and by about 20 percent for lateral displacement of 1 inch.

On the basis of the preliminary results of this investigation, the 265-feet length limitation in Iowa for integral abutment concrete bridges appears to be very conservative.